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einer Patentanmeldung****Aktenzeichen:** 199 33 248.7**Anmeldetag:** 15. Juli 1999**Anmelder/Inhaber:**  
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fahrt eV, 53175 Bonn/DE.**Erstanmelder:** Zeiss Optronik GmbH,  
73447 Oberkochen/DE**Bezeichnung:** Athermalisiertes Teleskop**IPC:** G 02 B 23/06**Die angehefteten Stücke sind eine richtige und genaue Wiedergabe der ur-  
sprünglichen Unterlagen dieser Patentanmeldung.**

München, den 14. November 2005  
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Title: Athermalized Telescope

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Description:

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Athermalized Telescope

The invention relates to a telescope according to the preamble of patent claim 1.

5 A mirror telescope with a primary mirror and a secondary mirror, which are arranged spaced from each other by means of a mounting, is known, for example, from DE 39 40 924 A1. The mounting includes a telescope tube of Zerodur®. Likewise, a holding star of Zerodur® is provided for the mounting of the  
10 secondary mirror and is connected to the telescope tube.

The material Zerodur® is selected because of its low thermal expansion coefficient. An athermal behavior, particularly in the temperature range from 20°C to -50°C, is desirable in telescopes for optical telecommunications which are used in space since in  
15 such applications a readjustment during use is practically impossible.

In particular, deformations of the mirrors are disadvantageous since a displacement of the focal point is associated with them. Also, such a displacement of the focal  
20 point results in a defocusing. A nearly athermal behavior is obtained by the use of Zerodur; however, it is disadvantageous that this ceramic material is very brittle and can only be loaded to a limited extent.

Furthermore, invar is used as a material in telescopes.  
25 However, this material has a considerable thermal expansion coefficient so that the telescope has a temperature-dependent behavior.

The production of a mirror blank by a casting technique is known from DE 43 26 762 A. Silicon carbide is provided as a  
30 material.

It is known from U.S. Patent 5,579,333 to use ceramics of silicon nitride ( $Si_3N_4$ ) for the production of industrial mirrors.

The invention has as the object to provide a telescope which has a nearly athermal behavior at reduced costs.

5 A further object of the invention is to provide a telescope which has an increased mechanical loading capacity with the smallest possible weight.

The task of the invention is solved by features of claim 1.

10 The mounting includes compensation elements for a temperature-dependent change of the predetermined distance between the primary mirror and the secondary mirror. Because of this measure, it is possible to compensate for a change of the position of the focal point of the primary mirror due to thermal deformation of the mirror surface and the mounting. It is 15 possible by means of the compensation elements to adapt the position of the secondary mirror to the new focal length of the primary mirror. In this way, the telescope is always optimally focused independently of temperature.

20 It has been found to be advantageous to arrange the compensation elements parallel to an optical axis defined by the optical elements. In this way, the greatest possible length change of the compensation elements relative to the length extension of the compensation elements in the direction of the optical axis direction is obtained per temperature interval.

25 The material used for the compensation elements is to be selected in dependence upon the length of the compensation elements in the axial direction and in dependence upon the focal point displacement per temperature interval so that the length change of the compensation elements compensates for the 30 displacement of the focal point.

In particular, it has been found to be advantageous to provide a material for the compensation elements which has a greater thermal expansion coefficient. It is thereby possible to attain a large length change in dependence on the temperature 5 change.

It has been found to be advantageous to arrange the compensation elements in the region of the primary mirror so that there is no, or nearly no, temperature difference between the primary mirror, particularly the mirror member, and the 10 compensation elements. Thereby the compensation elements undergo approximately the same temperature change.

It has been found to be advantageous to use for the mounting a material with a sufficient thermal conductivity value and a very small expansion coefficient so that during exposure of the 15 mounting or the telescope tube to unilateral or unequal irradiation, a rapid temperature equalization takes place and the deformations due to a temperature gradient remain small. In this manner, stresses in the mounting itself and warping due to a local expansion resulting from temperature gradients are avoided. 20 In particular, with a seating in the shape of a star for the secondary mirror, a temperature gradient in the region of the seating of the secondary mirror results in a bending of the same, giving rise to a defocusing. The adaptation of the compensation elements is facilitated or even only made possible by the use of 25 a material with a very small expansion coefficient for the mounting since then primarily only the influence of the material of the mirror has to be considered.

The production costs could be minimized by the measure of producing the mirror body from SiN; this is of particular 30 interest for production in large numbers.

In particular, a replication process can be used for mirror manufacture when SiN is used, and aspheric mirrors can also thereby be produced at a favorable cost. In mirror manufacture by the replication process, very hard materials can be used which 5 also can be brittle and unsuitable for polishing. Ceramic materials above all are suitable here, which have a low weight as well as low expansion coefficients.

It has been found to be advantageous to provide C/C SiC® as material for the mounting. Especially if the mounting includes a 10 telescope tube, it has been found to be advantageous to make the telescope tube of C/C SiC.

Further advantageous measures are described in further dependent claims.

FIG. 1 shows a telescope with a primary mirror produced by 15 polishing technique and a mirror carrier of SiN; and

FIG. 2 shows a telescope with a mirror body of SiN and a primary mirror produced by replication technique.

The principal structure of a telescope 1 is first described with reference to FIG. 1.

20 The telescope 1 shown has a primary mirror 3 and a secondary mirror 27, the mirror surfaces (7, 28) of which are arranged facing toward each other. An optical axis 2 is defined by these two mirrors (3, 27). These two mirrors are connected to each other by means of a mounting 15 and are arranged at a predetermined axial distance 29 to each other.

25 In the embodiment example shown, the mounting 15 includes a telescope tube 17 arranged coaxially of the optical axis 2 and a seating 22 in the form of a holding star 23 for mounting the secondary mirror 27. The holding star 23 and the telescope tube 17 preferably consist of an identical material in order to

5 avoid stresses due to differing expansion coefficients of the materials. In the embodiment example shown, C/C SiC is provided as the material, which has a sufficient thermal conductivity value and a very small expansion coefficient, so that in the mounting 15 temperature gradients and deformations can occur only briefly, if at all, due to a unilateral irradiation. A large quotient formed by dividing the thermal conductivity by the expansion coefficient is to be sought.

10 A mirror seating 25 for the secondary mirror 27 is connected to the holding star 23. Compensation elements 19 in the form of three feet 21, arranged at an angular spacing of 120°, are provided on the end of the telescope tube 17 facing away from the secondary mirror 27. These feet 21 engage at one end around the end of the telescope tube 17 and, at the other end, are connected 15 to a mirror mounting 11 of the primary mirror 3. A ring could also be provided as a compensation element, of a material which has a thermal expansion coefficient other than that of the mounting. It is crucial that the compensation element(s) has/have an extension in the direction of the optical axis 2.

20 The mirror mounting 11 is mounted on a mirror carrier 12 which, in turn, is isostatically received by the mounting elements 9. The mirror mounting 11 as well as the primary mirror 3 are arranged coaxially to a tube 13, which is arranged on the optical axis 2 and, in turn, includes a collimator.

25 In the embodiment shown, the primary mirror 3 includes a mirror member 5 of quartz glass which is provided with a mirror surface by polishing technique. The mirror mounting 11 is of invar, and the mirror carrier 12 is of SiN. C/C SiC® is provided for the mounting 15.

30 In this telescope 1, the radiation striking the primary

mirror is deflected onto the secondary mirror and this radiation is focused via the tube 13 by reflection at the secondary mirror 27.

With a heating of this telescope 1, particularly of the 5 primary mirror 3, the focal length of the primary mirror 3 is shifted to greater distances. The distance 29 predetermined by the mounting 15 is increased by the compensation elements 19, which are likewise arranged in the region of the primary mirror 3, so that no displacement of the focal point takes place.

10 The embodiment example shown in FIG. 2 differs principally because of the primary mirror 3. In this embodiment example, the primary mirror 3 was made by replication technique with a mirror member 5 of SiN.

15 In particular, aspheric mirror surfaces 8 can be produced at a favorable cost in replication technique. Very hard, and in some circumstances brittle, materials can also be used, which do not have to be polishable. Such stiff materials generally have low thermal expansion coefficients. Because of the stiff material for the mirror member 5, no separate mirror mount 11 and 20 no mirror carrier 12 are required, as was necessary in the embodiment example according to FIG. 1. From the stresses arising in the mirror member 5 with the replication technique, only very small deformations result due to the shrinkage of the replication resin.

25 The mirror member 5 is connected to mounting elements 9 by means of which the mirror member 5 is accommodated isostatically. The mirror member 5 is provided on its outer radius with projections 10 on which compensation elements 19, which are again formed as feet, are supported with one of their ends. A ring of 30 a material, which has a thermal expansion coefficient other than

that of the mounting 15, could also be provided as the compensation elements 19. In this embodiment example, the mounting 15 and the holding star 23 are of C/C SiC. It is crucial that the compensation element(s) 19 has/have an extension 5 in the direction of the optical axis 2. The material for the compensation elements 19 is to be selected in dependence on the mirror member 5 used. The material for the compensation elements is to be selected in dependence on extension of the compensation elements in the axial direction at a reference temperature and in 10 dependence on the focal point displacement to be expected per temperature change. The length change of the mounting 15 in the axial direction in dependence on the temperature is also to be considered so that this length change plus the length change of the compensation elements 19 gives the displacement of the focal 15 point.

List of Reference Numerals

- 1 telescope
- 2 optical axis
- 3 primary mirror
- 5 mirror member
- 7 mirror (surface)
- 8 aspheric mirror
- 9 mounting element
- 10 projections
- 11 mirror mount (polishing technique)
- 12 mirror carrier
- 13 tube with collimator
- 15 mounting
- 17 telescope tube
- 19 compensation element
- 21 feet
- 22 seating
- 23 holding star
- 25 mirror seating
- 27 secondary mirror
- 28 mirror surface
- 29 predetermined distance

Patent Claims:

1. Telescope having a primary mirror and a secondary mirror, which are arranged at a predetermined distance from each other by means of a mounting, characterized in that the mounting (15) includes compensation elements (19) for a change of the predetermined distance (29) between the primary mirror (3) and the secondary mirror (27) in dependence upon the temperature.  
5
2. Telescope of claim 1, characterized in that the compensation elements (19) are aligned in axial direction with reference to an optical axis (2) fixed by the primary mirror (3) and the secondary mirror (27).
3. Telescope of claim 2, characterized in that the compensation elements (19) are arranged in the region of the primary mirror (3) coaxially thereto.
4. Telescope of at least one of the claims 1 to 3, characterized in that the primary mirror (3) is connected by the mounting (15) via the compensation elements (19).
5. Telescope of at least one of claims 1 to 4, wherein the mounting includes a telescope tube having an end facing toward the primary mirror and an end facing toward the secondary mirror, characterized in that as compensation element (19), at least three feet (21) are preferably supported on a mirror carrier (5), the three feet (21) carrying the end of the telescope tube (17), which faces toward the primary mirror (3) and, at the other end, are connected to the primary mirror (3).  
5

10 the mirror carrier (5) supporting the mirror surface (7) of the primary mirror (3).

6. Telescope of at least one of the claims 1 to 5, characterized in that the compensation elements (19) have a thermal expansion coefficient departing from that of the mounting (15).

7. Telescope of claim 6, wherein the primary mirror includes a mirror carrier of Zerodur, characterized in that the compensation elements (19) at least partially comprise invar.

8. Telescope of claim 6, characterized in that the primary mirror (3) includes a mirror body (5) of quartz, which supports a mirror surface (7), and that the compensation elements (19) comprise, at least partially, titanium.

9. Telescope of claim 6, characterized in that the primary mirror (3) includes a mirror body (5) of SiN, which supports a mirror surface, and that the compensation elements (19) comprise, at least partially, aluminum or titanium.

10. Telescope of the preamble of claim 1, characterized in that the primary mirror (3) includes a mirror body (5) of SiN, which supports a mirror surface (7).

11. Telescope, especially of claim 10, characterized in that the mounting (15) is made of C/C SiC® as a material.

12. Telescope of claim 10, characterized in that the primary mirror (3) is produced in replication technology.

13. Telescope of at least one of the claims 1 to 12, characterized in that the mounting (15) is made of a material which has a thermal expansion coefficient which is less than  $1 \cdot 10^{-6}$ .

14. Telescope of at least one of the claims 1 to 13, preferably of claim 13, characterized in that the mounting (15) is made of a material having a density of maximally  $2.5 \cdot 10^3 \text{ kg/m}^3$ .

15. Telescope of at least one of the claims 10 to 14, characterized in that the mirror body (5) is connected directly to the support element (9) for the isostatic support and the mounting (15) is supported on the mirror body (5).

SummaryAthermalized Telescope

(FIG. 1)

The invention relates to an optical system comprising at least one first and second optical element, whereby the optical elements are arranged at a predetermined distance from one another, using a mounting. The mounting comprises compensation elements for modifying the predetermined distance between a first optical element and a second optical element, according to the temperature. The optical system is a telescope and the distance between the primary mirror and the secondary mirror is modified according to the temperature.

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